A WINTER PITFALL TECHNIQUE FOR WINTER-ACTIVE SUBNIVEAN FAUNA[1]

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ABSTRACT: An adapted pitfall trap is described to sample the subnivean fauna active between the frozen ground and snow layers. A pitfall trap is placed in a frame adaptor before the first snow. An apparatus made of two wood boxes is placed over the pitfall; the frame box has no bottom and allows access to the pitfall from the top to gather samples. The open sides at the bottom allow organisms to enter the pitfall through the subnivean space. The bottom portion of the second box is closed and accumulates fallen snow. To service the traps, the removable snow column is lifted giving full access to the pitfall trap. The use of a fine mesh sifter improves the efficiency of the gathering of the samples; all sizes of organisms are transferred to alcohol in a single and simple procedure that avoids damaging specimens. Two factors related to the trap were studied: 1) the winter-trap did not cause any cold air induction to the subnivean level; the temperature averaged –5°C both under the snow and in the trap providing a stable environment despite ambient temperature variations above the snow. 2) Trampling of the surrounding snow caused by the regular servicing of the traps had no effect on the presence or absence of taxa collected, although a significant effect on the numbers of Acarina was observed.

KEY WORDS: Winter, sampling, snow, microhabitat

The subnivean space is the habitat between the frozen ground surface and the snow layer. It originates from bacterial activity in the ground layers (Coxson and Parkinson, 1987) that creates CO_2 and water vapor. The gas pressure erodes the snow layer in contact with the ground in an upward movement (Pruitt 1970). In combination with the frozen ground surface heterogeneity, this ongoing activity results in a space of variable dimensions, from a fine network of a few mm up to 8 cm (Coulianos and Johnels, 1962).

The ecological stability of the subnivean space strongly depends on the insulating properties of the snow (Mail, 1930; Näsmark, 1964; Aitchison, 1974). According to Pruitt (1970), snow accumulation of 20 cm is the threshold at which subnivean temperature becomes independent of ambient temperature, resulting in a stable environment. Well-adapted, winter-active fauna circulate in this habitat (Aitchison, 1979a, b, c, d, 1984; Merriam et al., 1983) but remain understudied due to the difficulty of sampling this fauna. Pitfall traps have been used extensively in ecological assessment, and several modifications were made to improve the efficiency or to better suit particular habitats. To study subnivean fauna, Aitchison (1974; 1979a) used a modified pitfall technique, elaborated from Näsmark (1964), consisting of a roof installed over the pitfall to prevent snow accumulation in the trap. However, this method was found inadequate for winter conditions where snow accumulated up to 1 meter.

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This paper describes a new type of winter pitfall trap and inherent methodologies that improve and facilitate collecting samples in winter conditions. Two factors regarding the technique were also investigated: cold air induction at the subnivean level due to the winter-trap and the effect of snow trampling due to the servicing of the traps on a regular basis.

METHODS

1) Study area

This study was conducted in the southern mixed-boreal forest of the Lake Duparquet area, Québec, Canada (48° 30' N, 79° 13' W). At this latitude, the snow covers the ground for approximately 6 months, — October to March — and traps were used over that period. The traps were tested in each of the major forest types of the mixed boreal succession: deciduous stands, dominated by aspen (*Populus tremuloides* Michx.), the mixed stands, which consisted of balsam fir (*Abies balsamea* [L.] Mill.), white spruce (*Picea glauca* [Moench] Voss), paper birch (*Betula papyrifera* Marsh.) and some P. tremuloides Michx., and the coniferous stands, dominated by white cedar (*Thuja occidentalis* L.) and balsam fir (*Abies balsamea* [L.] Mill.). See Leduc et al. (1995) and Bergeron (2000) for a detailed description of the ecological succession.

2) The winter pitfall trap

The described methods were used over three winter sampling seasons from 1993 to 1996. Dates and number of traps used are given in table 1. Typically, five winter pitfall traps were installed in a transect in a given forest site, and each trap was separated from the next by a distance of 7-10 meters.

Trap installation

The winter-pitfall trap should be deployed before the first snow falls, ideally shortly after the first ground frost. The installation of the pitfall trap itself (shown in Fig. 1a) can occur earlier in the season before the installation of the winter apparatus (shown in Fig. 1b).

The pitfall trap consisted of a 17 x 20 x 4 cm solid plastic pan inserted in a 28 x 30 cm wood frame adaptor. The adaptor and pitfall used are commercially available from Argiope® as items BAC-102 and BAC-205. The edges of the plastic pan expanded laterally and fitted perfectly into a groove in the wood frame. The ground was cut with a knife around the adaptor. The middle section of the hole was dug deep enough (about 15 cm) to clear the pan and minimize its uplift over the adaptor from soil and ice movements caused by frequent freeze and thaw cycles. The wooden frame was fitted flush with the ground. Brushing around the wood frame with a hand broom eliminated free particles and dirt that could be drawn into the pan by the movement of air when emptying the traps. After preservative liquid (30 percent ethylene glycol mixture) was added to the pan, it was placed in the wooden frame adaptor and the pitfall was ready to collect (Fig. 1a).

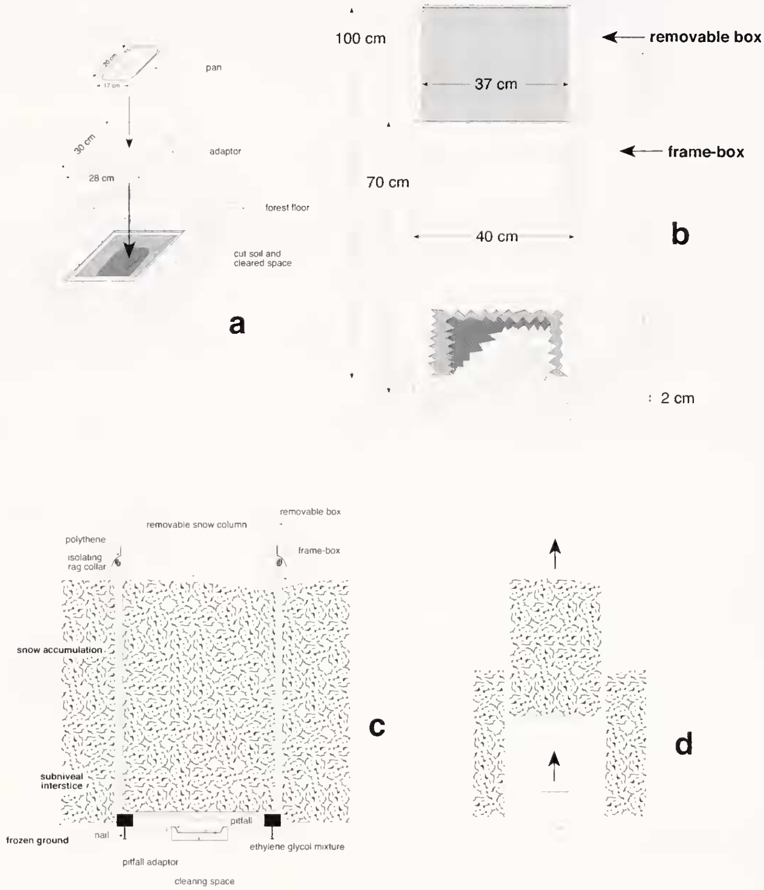

Figure 1. Winter-trap specifications and set-up. a) pitfall and wooden frame adaptor. b) winter apparatus design and size specifications. c) side view of winter-trap, specimens can reachi the pitfall through the 2 cm space on each side of the frame-box. d) removing the snow column gives access to the pitfall, which is lifted by hand through the frame-box.

The next step consisted of setting up the winter device (Fig. 1b). Two independent sections made of commercial plywood and wood blocks were assembled: the frame-box (the outer section in contact with the ground) and the removable column (the inner box with a closed bottom). Once assembled, the frame-box was placed on the ground to enclose the pitfall (Figs. 1b-c). Four blocks (5 x 10 x 10 cm, see Fig 1b.) at the bottom corners were the only contact with the soil, leaving a 2 cm space between all sides and the soil, giving free access to the pitfall (Figs. 1b-c). Three inch (7.6 cm) nails were inserted in the blocks, allowing the frame-box to be firmly anchored in the soil (Figs. 1c-d). The pitfall pan was then filled to a quarter full with preservative liquid and placed in the adaptor, which was reachable through the frame-box. The removable column was then fitted into the frame-box. A rag collar was placed between the two boxes to prevent cold air induction in the apparatus, and a polyethylene band was tacked over the insulating collar to prevent it from icing (Fig. 1c). The column was closed at the bottom and snow accumulated inside the column as well as on the ground, but the subnivean interstice allowed organisms to access the pitfall.

Servicing the traps

The removable column was lifted slowly to prevent any strong air current that could have caused movement of debris at ground level entering the pitfall (Fig. 1d). The column was then laid on its side, providing a straight, working surface for the subsequent steps. The pan was then removed through the open box (Fig. 1d) and the contents sifted over a small bucket (Fig. 2a) with a fine mesh nylon strainer (110 µm). The contents of the pan and the pan were carefully cleaned with a flask of ethyl alcohol over the strainer. Specimens were then concentrated with the ethyl alcohol flask to the center of the strainer (Fig. 2b). The strainer was then flipped over a funnel fitted to a cap and a jar (see Fig. 2c), and a final wash with alcohol allowed the transfer of all organisms into the jar in one simple procedure (Fig. 2d). This method was preferable to the use of forceps in the field, because efficient sorting of small organisms (such as mites) requires laboratory conditions and the use of a stereoscope.

Resetting the trap

The outside parts of the pan and the inner sections of the frame-box must be free from ice. It was also necessary to remove the ice from the 2 cm space at the bottom of the frame-box to ensure free access from the subnivean interstice. The pan was placed back in the adaptor, and the removable column was fitted back into the frame-box and re-isolated with the rag collar.

3) Factors that may influence trap catch

The use of the winter pitfall traps for two seasons (1993-1994 and 1994-1995), raised questions about possible biases associated with the methodology. The 1995-1996 season was devoted to testing two factors that may have influenced catches: 1) verification whether the use of the winter pitfall trap caused cold air induction in the subnivean space that may have influenced faunal activity; and 2) testing the effect of the trampling of snow due to the servicing of the traps on a regular basis.

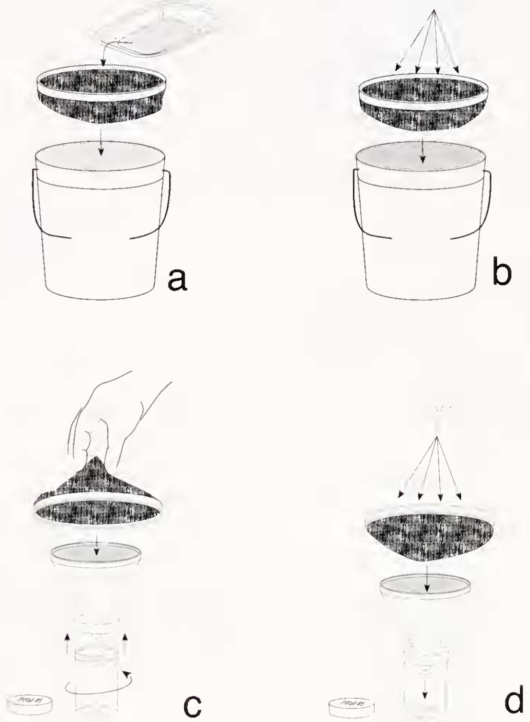

Figure 2. Collecting specimens and transfer in ethyl alcohol. a) the contents of the pan are sifted though a fine mesh strainer over a small bucket. b) specimens are concentrated in the center of the strainer with an alcohol flask. c) the strainer is flipped while grabbing the center by hand. d) specimens are washed in the funnel and put in a jar.

Cold air induction

Before winter, a pair of programmable thermometers with probes was installed a few millimeters above the ground surface. One was placed in a winter-trap and the other in the subnivean space, 10 meters away from the trap. The temperatures and snow depth were noted daily for the first two months of winter (November 3, 1995 – January 12, 1996).

Trampling effect

Ten winter traps were set up in a transect separated from each other by 7-10 meters in the cedar/balsam fir forest. Five traps were emptied every two weeks (5 visits in total) while the others were never visited before a final visit halfway through the winter season (February 12). In order to compare the trampling effect, data from the samples that were collected every two weeks were pooled for each trap. The five traps serviced on a regular basis could therefore be compared with the five traps that were never visited; each trap having been active for the same period of time. Similarity matrices measuring the association between objects (samples) were calculated with SIMIL 3.01 in the R package (Legendre and Vaudor, 1991). The Sørensen (2a/2a+b+c) – presence/absence sensitive – and Steinhaus coefficients (2W/A+B) – which accounts for presence/absence of taxa and abundance – were selected [see Legendre and Legendre (1998) for details]. Mantel tests (Mantel, 1967) were then performed with the MANTEL 3.01 program in the R package. This analysis tests by permutation the correlation between the similarity matrices (species x stations) and a binary matrix coding for treatment (trampling/non-trampling), as suggested by Legendre and Legendre (1998) for similar data.

RESULTS

The specimens collected, summarized in Table 1, are given to show the diversity of the subnivean fauna collected with this technique. All collections occurred in the presence of a snow layer that covered the ground for about six months at this latitude. A total of 22,419 specimens were collected representing 13 orders. An average of 19 specimens was collected per trap/week. Acarina were the most abundant in the collections followed by Collembola, Araneae, and Diptera.

Table 1. Overview of collected organisms: number of weeks of sampling, number of traps, and abundance of organisms

	1993-94 From 1 November to 23 April 25 weeks 15 traps (5 traps per forest type)	1994-95 From 30 October to 16 April 24 weeks 30 traps (10 traps per forest type)	1995-96 From 3 November to 12 February 10 weeks 10 traps (all set up in the cedar forest)
	Total abundance	Total abundance	Total abundance
Acarina	2274	4255	4891
Araneae	622	1745	106
Chilopoda	2	9	0
Coleoptera Staphynilidae (A)*	55	254	12
Coleoptera others (A)	10	118	2
Coleoptera immatures	42	51	65
Collembola	958	4227	1005
Diplopoda	3	0	0
Diptera (A)	101	1401	7
Diptera immatures	11	141	6
Homoptera Aphididae	1	3	0
Hymenoptera (A)	6	5	1
Lepidoptera (A)	1	5	0
Lepidoptera immatures	2	1	0
Opilio	3	3	0
Pseudoscorpionida	1	4	0
Symphyla	0	10	0
Total	4092	12232	6095

Grand total
22419 organisms

* (A) = Adults

Cold air induction test

The subnivean temperature was similar to the temperature recorded in the winter-trap. The two temperature curves were barely distinguishable when a snow layer was present. They both averaged -5°C with a snow cover of 20 cm or more, and external temperature showed little influence, despite the fact that extreme temperatures (-40°C) were recorded (Fig. 3).

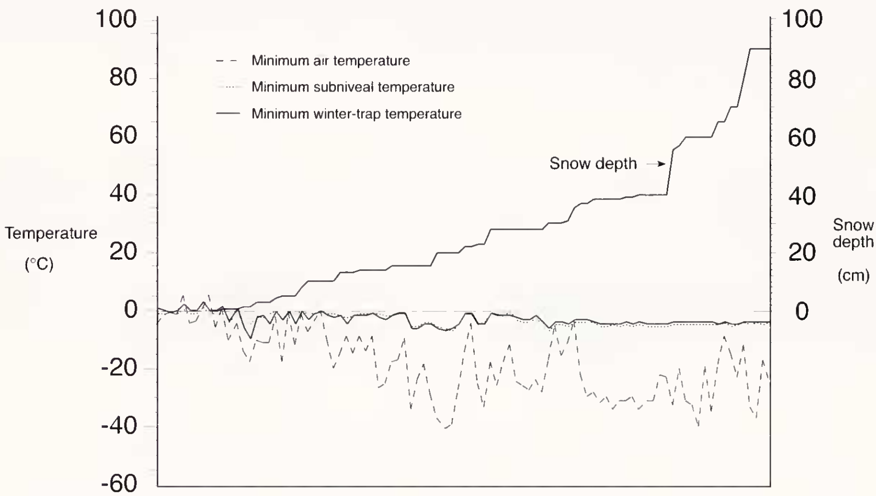

Figure 3. Relation between air, subniveal, and winter-trap minimum temperature and snow depth. The data were gathered from November 3, 1995 to February 12, 1996, with 2 programmable thermometers: one placed in a pitfall trap and a second one placed in the subnivean space a, 10 meters away from the trap.

Trampling effect

The Mantel correlation done with the Sorensen similarity matrix did not reveal any significant relationship between the traps visited every two weeks and those only emptied at the end of the experiment. However, in using the Steinhaus coefficient, which also accounts for abundance, a significant relation was found (R = 0.357; P = 0.0176). A third analysis using the Steinhaus coefficient excluding Acarina was not significant (Table 2).

DISCUSSION

The techniques described above allow sampling in winter conditions characterized by deep snow accumulation, which was not possible with previously known methods. The high number of specimens collected (22,419) and the general richness are evidence of the success of the method. Effectiveness was difficult to compare with other studies done on subnivean fauna because of differences in habitat, trapping effort, experimentation time, and differences in latitude and related winter conditions. However, Näsmark (1964) reported an average of 12 organisms per trap/week while this study found an average of 19 organisms per trap/week. The numbers of arthropod orders collected in this study (13 orders) is, however, similar to the results Merriam et al. (1983) (13 orders) and Näsmark (1964) (11 orders). Interestingly, numbers of Acarina found in the two later studies were low: a total of 127 mites found by Merriam et al. (1983) and 79 by Näsmark (1964) compared to the 11,420 mites collected in this study. This striking difference could be attributed to a deficiency in the other methodologies in collecting smaller organisms, but also to faunistic differences between forest habitats, which makes comparison of results hazardous. The results of this study, however, clearly show that this methodology is well-suited to smaller organisms. Several points can be made regarding the advantages of the winter pitfall trap technique described here. 1) The surface covered by the pitfall is bigger, 17 x 20 cm compared with 8 cm as used by Näsmark (1964), Aitchison (1984) and Itämies and Lindgren (1989). A better trapping effort minimizes variability among samples, which is a problem with pitfall trapping (Adis, 1979). 2) The use of a wood frame adaptor reduces the amount of dirt and particles in the samples, which saves a lot of sorting time in the laboratory. 3) A removable pitfall allows one to replace the pan when damaged, which occurs easily in cold weather. 4) The use of the technique shown in figures 2a-d is important for collecting very small arthropods, such as mites. The method of transfer of specimens into alcohol is appropriate for all sizes and allows one to do it in a single and simple procedure while avoiding damage to specimens. Delicate manipulations with forceps or brushes (Aitchison 1984) are hazardous in windy situations as well as unreliable for smaller specimens. 5) This method allows one to reuse ethylene glycol and verify its concentration in a routine procedure. 6) The use of a removable snow column ensures that identical insulating conditions are found under the trap and in the subniveal environment. 7) The total time required to service one winter-trap is brief, averaging 7 minutes. Such efficiency is important when a high number of traps have to be visited.

Cold air induction and subnivean temperature

The aim of this simple comparison was to ensure that the winter-trap did not create a cold air induction to the subniveal level and bias the specimens collected. Similar temperatures were found in the winter-trap and the subniveal environment. The use of the winter-trap did not cause any detectable cold air induction that could create biases. The minimum temperature reached in the subniveal space is similar to that observed by Aitchison (1984) and Näsmark (1964) (averaging -5°C) but is lower than the average reported by Mail (1930), Coulianos and Johnels (1962) and Hayward (1965) (being just under the freezing point). The latter authors may have obtained a slightly higher temperature because winter conditions were not as severe where they conducted their experiments.

Trampling effect

Trampling of snow did not cause any effect on the taxonomic composition of the collections at the order level with the Sørensen coefficient, which is only sensitive to presence/absence of taxa. However, the use of the Steinhaus coefficient, which is abundance sensitive, revealed a significant effect (R = 0.357, P = 0.018). The trampling effect was mainly due to the reduction in Acarina abundance, as shown by the non-significant result when mites were excluded from the analysis using the same coefficient (R = 0.211, P = 0.052). Although, the latter values were close to a significant level and suggested that trampling may have also affected the abundance of organisms other then mites, but not the taxonomic composition of collected orders.

As the sampling season progressed, the snow conditions changed. In the first part of the season, snow depth was thin, and trampling at that stage may cause snow compaction and destruction of the subnivean space. Although the compaction may only be temporary due to the continuous bacterial activity that restores the subnivean space, working only on one side of the trap will limit biases, leaving three undisturbed sides for full access to the pitfall through the subnivean space. As the season progresses, the surface snow layer develops a more robust and partially iced structure that can easily support more weight, and may cause fewer biases in collection.

Technical considerations and recommendations

During this experiment, methodological problems were encountered and are briefly mentioned here. Small rodents are also winter-active in the subniveal environment (Coulianos and Jonhels, 1962; Hayward, 1965). They can dig tunnels that intercept with the winter-trap. There was not enough ethylene glycol to cause drowning, but the samples were contaminated with dirt, feces and fleas. Although requiring more hand-sorting time, specimens were still as numerous and in good condition. Also, propylene glycol could be used as an alternative to ethylene glycol, as it is less toxic to mammals.

Another problem can occur late in the spring when the melting of the snow results in water accumulation under the residual snow and causes flooding of the forest floor (Jahn, 1970). This ecological perturbation in forested habitats is an important mortality factor for soil organisms (Joy, 1910; Uetz et al., 1979; Danks, 1991), and will also flood the winter traps and ruin samples. Frequent visits to the traps at this critical period during the sampling season will reduce this effect on the collections.

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